Climate Change Scenarios for the Congo Basin

Climate Change Adaptation Options for the Congo Basin Countries

Linda van Garderen
Fulco Ludwig

On behalf of
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
of the Federal Republic of Germany

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CSC
Climate Service Center
Germany
Eine Einrichtung der GKSS-Forschungszentrum Geesthacht GmbH

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Authors: Garderen, Linda van, Fulco Ludwig
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Cover photo: "A farmer watering his field of sugar cane" @ AlidaVanni/istockphoto.com

ABSTRACT

During the last decades, the importance and seriousness of climate change and it's impacts have become more and more understood. The climate is already changing and therefor adaptation to these changes need to be made. Central Africa needs to adapt to climate change just as much as the rest of the world. This report is focused on the COMIFAC countries, or the Congo River Basin countries: Cameroon, Equatorial Guinea, Sao Tome & Principe, Gabon, Republic of Congo, Central African Republic, Democratic Republic of Congo, Rwanda and Burundi. Based on the impact analyses of the previous chapter, this chapter discusses the most appropriate adaptation measures for the region. This chapter explains the basic principles of climate change vulnerability and adaptation such as adaptive capacity, forms of adaptation, the adaptation cycle, maladaptation, adaptation deficit and no-, low- and high regret adaptation options.

The second part of the report focusses on the different climate change adaptation options for central Africa within four sectors: Agriculture, Forestry, Water and Energy. Even though these four sectors are discussed there is also a strong overlap. In total 52 climate change adaptation measures are listed in the annex and discussed in the report. Most of the adaptation measures fit under a few basic climate change adaptation principles:

- Spreading of risk by diversification
- Buffer building by reforestation / agroforestry
- Preparedness for extreme weather events, droughts and floods.
- Food and water security
- Sustainable energy supply
- Education and awareness raising
- Effective management

Most of the COMIFAC member countries still have very big development challenges. The general income tends to be low and there are still high poverty rates. These immediate development needs are overall more important than climate change adaptation. However future development also creates opportunities for adaptation. To avoid wrong investments and to reduce future cost of adaptation, climate change adaptation should be integrated in future development plans.

Keywords: Climate Change, COMIFAC, Congo, River, Basin, Adaptation, Africa, Agriculture, Water, Energy, Forestry

ACRONYMS

CRB	Congo River Basin
CWP	Crop Water Productivity
COMIFAC	The Central African Forest Commission
GDP	Gross Domestic Products
IFRC	International Federation of Red Cross and Red Crescent
MTS	Modified Taugya System
NAPA	National Adaptation Programme of Action
NC	National Communications
NGO	Non-Governmental Organisations
PWS	Public Water System
REDD	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
RWH	Rain Water Harvesting
TWB	The World Bank
UNFCCC	United Nations Framework Convention on Climate Change
UKCIP	United Kingdom Climate Impacts Programme

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1. INTRODUCTION

Even with if highly effective mitigation measures are introduced in the near future the climate will continue to change in the coming century. So to reduce negative impacts of future climate change there is a need for adaptation. The IPCC (2007) defined adaptation as "actual adjustments, or changes in decision environments which might ultimately enhance resilience or reduce vulnerability to observed or expected changes in climate'. Many previous reports have highlighted the need for adaptation especially on the African continent. However most of the work on adaptation in Africa has focussed on the Semi-arid zones and the Mediterranean part of the continent. Much less is known about adaptation in the Tropical zone of the continent focusing on the question: Which climate change adaptation measures are most efficient and applicable for the Congo basin region? This chapter aims to review the publications on climate change adaptation in the region and summarize important knowledge on climate change adaptation outside the region. This chapter first presents a framework for adaptation and then different adaptation options discussed. Through literature study, applicable adaptation measures from within and outside the COMIFAC region which are applicable inside the region have been summarized. The measures are explained and different practical examples are discussed.

2. Future climate change and potential impacts

Adaptation should focus reducing the negative impacts of future climate change. Climate change scenarios and potential impacts are discussed in detail in the previous chapters. From these analyses the most important climate change impacts are a future change in rainfall characteristics increasing the intensity of heavy precipitation events and an increased number of dry spells during the rainy season. In addition the average and extreme temperatures will increase in the future. This changes in temperatures and rainfall will results in an intensification of the hydrological cycle. This will result in more hydrological extremes (floods and droughts).

The six climate scenarios analysed in the hydrologic assessment indicated the run-off and river flows will especially increase in the wet season. While in the dry season several scenarios indicated a reductions in river flows. These changes will not reduce the total hydropower production potential but it will make hydropower production in the region less reliable. Low flow events will become more frequent causing periods will low power generation potential. Also the chance of dam failure and the need for emergency releases will increase due to more frequent extreme rainfall and high river flow events.

Agricultural production systems will mostly suffer from the higher temperatures. In tropical part of the region agricultural water stress will not increase due to climate change. In the savanna regions in both the northern and southern edges of the region future climate change could increase future water stress resulting in lower potential agricultural production. Agricultural systems will also be affected by a more variable future climate. Higher rainfall intensities increase erosion and flood risks. Dry spell during the wet season can potentially reduce crop production.

The most pressing adaptation needs for the different sectors but also for the whole economy will be to cope with a more variable future climate.

3. CLIMATE CHANGE VULNERABILITY AND ADAPTATION

During the last decades, the awareness of the potential seriousness of climate change and the impacts have rapidly increased. Ten to twenty years ago adaptation used to be connected with giving up avoiding climate change but it is now widely accepted as essential because it has become more and more likely that climate will continue to change in the future. So in addition to reducing greenhouse gas emission to reduce climate change will use need to adapt to future change to reduce climate change vulnerability

3.1. What is climate change adaptation?

To understand the what adaptation means, it is necessary to understand the concept of vulnerability to climate change. Vulnerability can be seen as the risk of exposure to a certain hazard. Each country, region or sector is exposed to different kinds of hazards. For example, the risk of the hazard of flooding due to sea level rise is higher in Cameroon than in Burundi, because Burundi has no coast-line.

Figure 1. Vulnerability scheme

Vulnerability is the combination of impacts and adaptive capacity (Figure 1). So vulnerability can be high because of high impacts and / or low adaptive capacity. If an area is impacted by a certain hazard, and it is able to respond successfully to this by adjusting behaviour, resources or technologies, the area has enough adaptive capacity. With such adaptive capacity the area is not vulnerable to this specific hazard. However if there is no or little adaptive capacity the area is considered to be vulnerable (Parry and Intergovernmental Panel on Climate, 2007). Every area has a specific adaptive capacity to each existing hazard. For example, country A has a high adaptive capacity, meaning solutions available, to deal with heavy rainfall, country B does not and is therefore vulnerable to floods and erosion. The context determines the adaptive capacity of the area (Smit and Wandel, 2006).
Impact is the combination of exposure and sensitivity. Exposure is the absolute change in a particular climatic indicator, for example, a shorter rainy season, higher maximum temperatures or sea level rise. These changes can only cause an impact if the area is sensitive to the exposure. A country that has no coastline is not sensitive to sea level rise. Low sensitivity means low impacts. If on the other hand the area is very sensitive to a certain exposure (or change), the impact will be very high. For example agricultural systems are highly sensitive to changes in rainfall.

Still, an area is only vulnerable if there is no, or only little, adaptive capacity to deal with the consequences of these impacts (Figure 2). Wealth, infrastructure, knowledge, equity, etc. are indicators for adaptive capacity. Adaptation can be implemented as an act (building dams) or teaching how to act (education, etc.). In the many African countries, the adaptive capacity is relatively weak due to low economic wealth, limited education and weak institutions. However at community level there is sometimes a remarkably high level of resilience for different climate extremes. Different communities have developed skill to survive long term drought and can respond quickly to changing weather conditions.

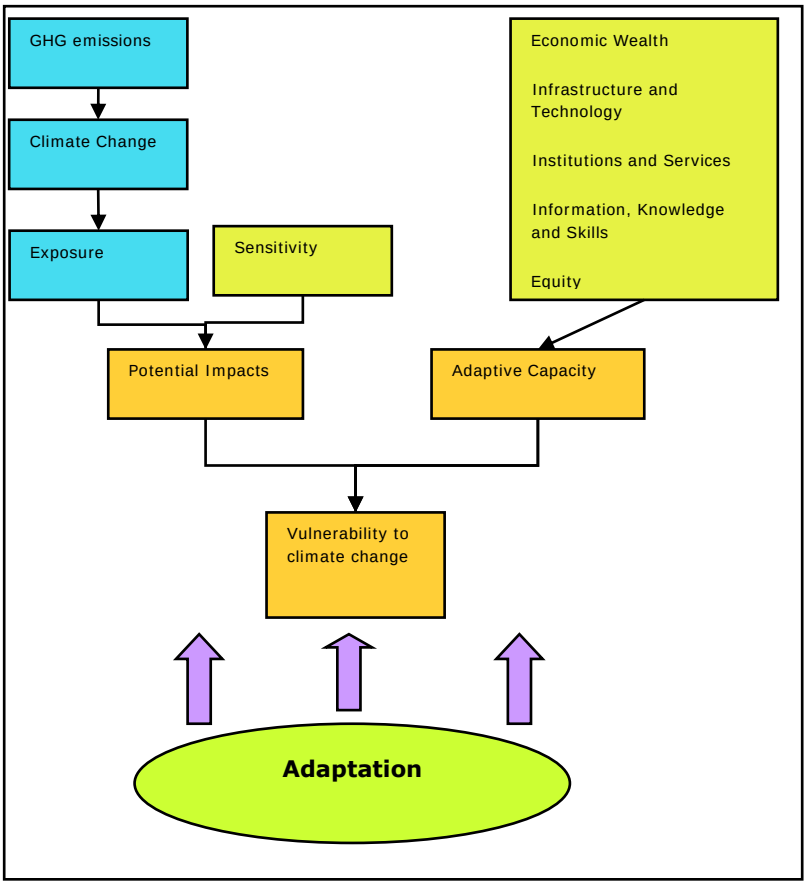

Figure 2. Adaptation framework

Historically, vulnerability has been approached from two points of view, the top-down and bottom-up-approach (Figure 3). The Bottom-up approach is often used more in social sciences studies, with focus on vulnerability of society or communities. It derives its data from studying the existing local social adaptive capacity to climate change. From that information the adaptation options are considered and the vulnerability of the area is analysed. This approach is often used by NGO's at community level.

The Top-Down approach is commonly used in climate change adaptation policies. It focuses on the physical science of climate change and biophysical vulnerability. To get data on what kind of climate change is to be expected; global climate change projections are used and then downscaled to the area for which the analysis is done. Based on that information an impact assessment is performed and the physical vulnerability of the area is assessed (Figure 3).

The two points of view should not be seen as opposite's but as complimentary. Within adaptation policy the physical vulnerability and social vulnerability should both be taken in account to create an effective package of adaptation measures (Dessai and Hulme, 2003). It is often difficult to use a large-scale analysis for local adaptation, thus especially for local adaptation the bottom-up approach was developed. The "Climate Change Scenarios for the Congo Basin" project follows a top-down approach because it aims at a large scale climate change analyses. For the Central African region limited climate

change information is available and this project aimed to fill that information gap. This analyses aim at identifying the main changes in the climate system and possible future impacts for a large region. For these large scale analyses the top down approach is usually most appropriate.

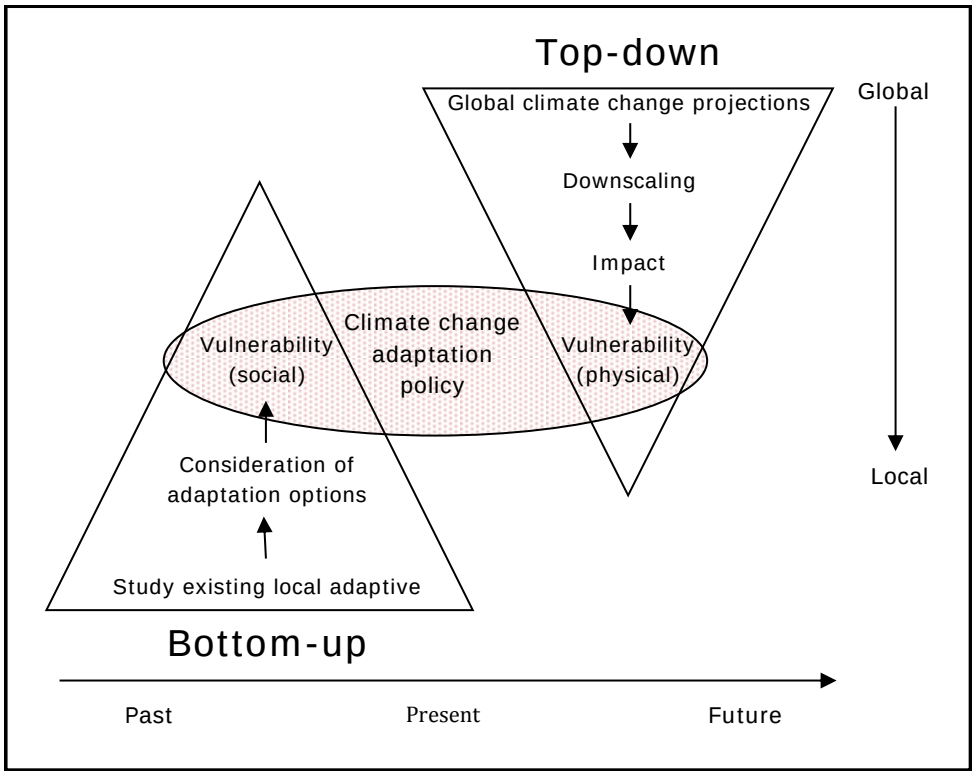

Figure 3. Top-down and Bottom-up vulnerability approaches for informing climate change adaptation policy (Dessai and Hulme, 2003)

To find out if an area is vulnerable, the coping range and adaptive capacity should be known. Figure 4 shows a schematic representation of vulnerability, coping range and adaptive capacity. For example, consider temperature as the climatic variable shown. The temperature is considered to be 'normal' as long as it stays within the dotted lines. If the variable crosses the dotted line but stays within the solid line, the 'boundary of adaptive capacity', one could speak of abnormalities but the population, or ecosystem, can deal with it by adapting . The resources and knowledge for adjustments are available, if used these kind of variations should not lead to great adverse impacts. If the temperature crosses the boundary of adaptive capacity, the population or ecosystem can no longer adjust to it with the available knowledge and / or resources it is provided with and therefore negative impacts are to be expected.

If it is known in advance that this extreme could happen, or the population who lived through such temperature extremes before and realises that it is possible to happen again, a choice can be made to prepare and gain the knowledge and / or collect the appropriate resources to adapt. As a result of this adaptation the adaptive capacity will increase. The solid lines move further away from each other (see Figure 4). Climate change could cause boundaries of adaptive capacity to be crossed. Climate change adaptation is focussing on moving the boundary to avoid or minimise the chance of crossing of it(Vincent, 2004). In conclusion, enlarging adaptive capacity will avoid (serious) impacts.

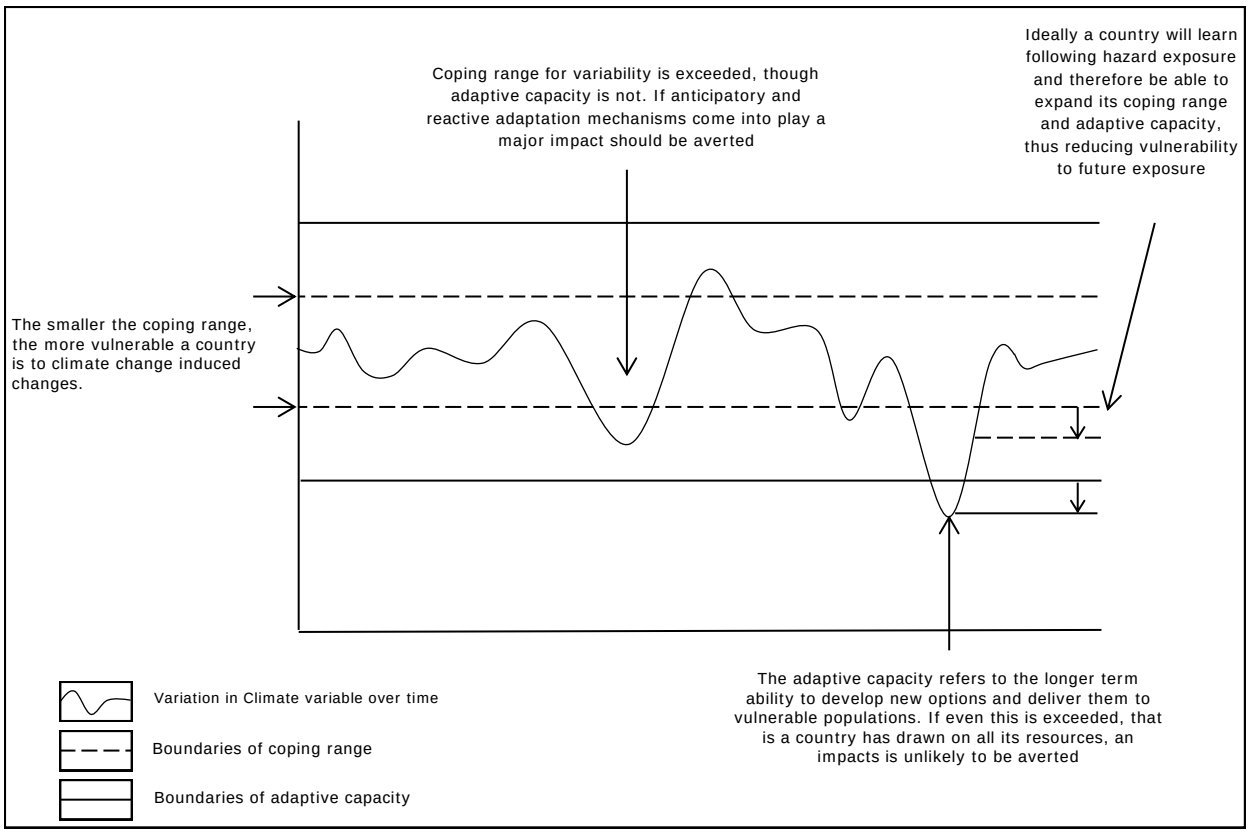

Figure 4. Framework of vulnerability, coping range and adaptive capacity (Vincent, 2004)

Climate change adaptation is complex, touching social, cultural as well as economic factors which need to be linked to the natural science of climate change, the physical changes (Sullivan and Huntingford, 2009). Although many communities, businesses and government institutions now realize that they need to adapt to climate change, how to do this is often unclear. To assist governmental institutions and businesses to adapt to climate change the adaption cycle was developed (Figure 5). For successful adaptation it is needed to know what to adapt to. Through a 'climate change impact and vulnerability assessment' the expected changes and the effects on the present state system, community or region can be mapped. After the impacts and the vulnerability of the area are known adaptation options can be designed and selected which is step two of the adaptation cycle. After selection of options, the adaptation measures should be evaluated. To deal with the residual vulnerability after the adaptation measures are implemented, the cycle can be followed again.

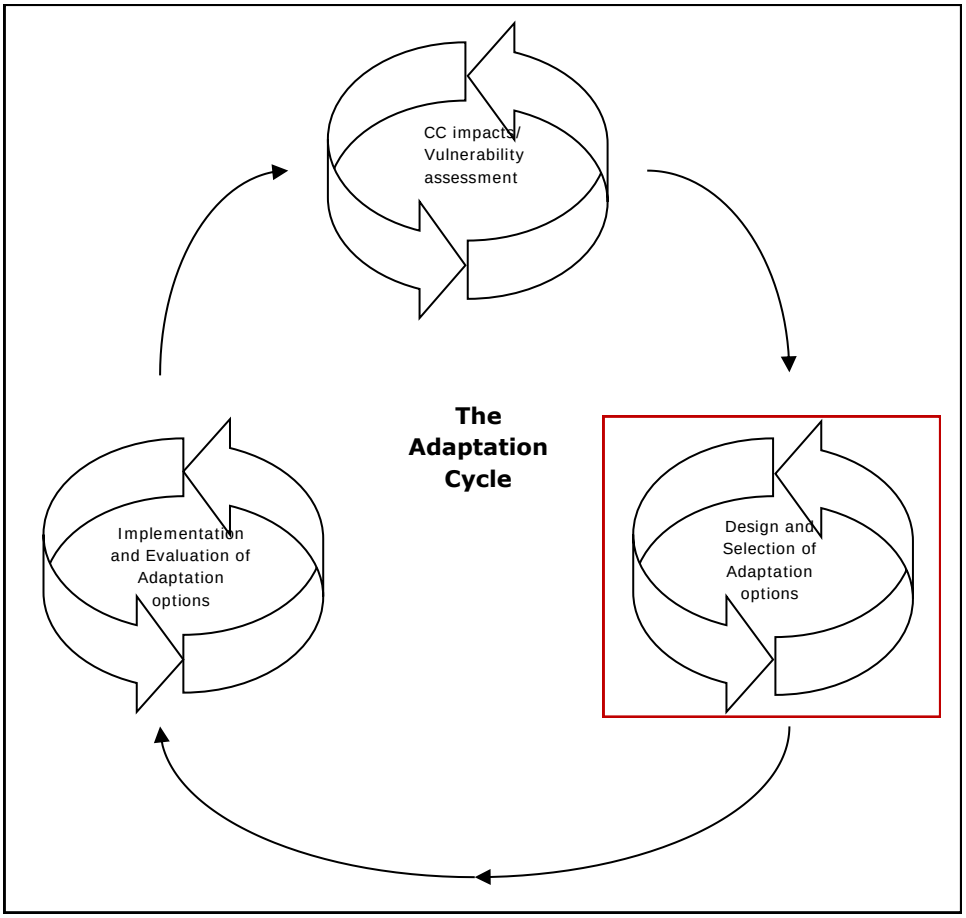

Figure 5. The Adaptation Cycle adapted from Goossen et al., 2011

The results first step of the adaptation cycle has been described in the in the previous chapters (Beyene et al., 2013; Haensler et al., 2013; Ludwig et al., 2013). This report is focussing on step two of the adaptation cycle (boxed in Figure 5). This report can be used to assist in the selection of climate change adaptation measures by providing a list of options from the Congo river basin area (see Chapter 4) as well as outside the Congo river basin region (see Chapter 5) which are implementable within the region.

There are different ways of adapting to changes, simple as well as complex activities are possible. Over time different structures to categorize these adaptation options have been developed. One could choose to *build adaptive capacity*: encouraging adaptation in the form of policy, education, financial stimuli, etc. Another strategy is to *deliver adaptation actions* which are 'hard adaptation measures': structural solutions like building dams, changing the irrigation system, etc. or 'soft adaptation measures': developing evacuation plans and seasonal climate forecast(Tompkins et al., 2009). In practise it is found most effective to combine both strategies, often soft measures are needed to activate hard measures ((De Loë et al., 2001)published, based on (Kates et al., 1985) and a more elaborate version in (Feenstra et al., 1998)). Climate change adaption measures can be categorized in three main categories:

1. *Accepting losses*

   This is basically the 'doing nothing' strategy. Within climate change adaptation assessments, the measures planned or implemented can be compared to this scenario.

   If for example the risk of floods increase, this means accepting the losses of crops, livelihoods and even lives, not acting in advance to prevent any losses from happening

2. *Preventing effects*

   Trying to protect the existing activities as they are and prevent losses or damages due to the climate change, measures are designed to prevent or lessen the effects.

   In case of flood risk increase, this usually means building dikes and other infrastructure. In case of higher water scarcity it can mean providing additional water to agricultural systems in order to avoid changes in the agricultural system.

3. *Changing uses and/or locations*

   If the activities as they used to be are no longer possible due to climate change, the use of the area could be changed. Activities can be moved to other areas or could be replaced by different activities.

   In the example of flood risk increase, this could mean moving the economic activity away from the river. In case of increased water scarcity or more frequent droughts this means changes land use by abandoning agriculture or a different crop

(Feenstra et al., 1998, Tompkins et al., 2009, UKCIP, 2011, Goulden et al., 2009)

Even though climate change adaptation is a well thought through concept, many adaptation actions are done without considering the action to be an adaptation to climate change at all. This spontaneous form of adaptation is called autonomous or unplanned adaptation. A simple thing such as carrying an umbrella because it might rain even outside of season, is a climate change adaptation measure. Though the individual who thought of bringing an umbrella was not specifically considering climate change. *Autonomous adaptation* occurs by itself, it is reactive. *Planned adaptation* is adapting by conscious intervention or preparation to climate change. It exists in the form of adaptation strategies and policies (Feenstra et al., 1998, Tompkins et al., 2009, The World Bank, 2009, Goulden et al., 2009).
It should be noted that what is considered spontaneous adaptation at one level may be seen as planned adaptation in another. On governmental level, actions are seen as autonomous adaptation if the people adapt without the governments interference. On the other hand, for the people themselves, that same action might be a planned adaptation measure, implemented after carefully considering climate change impacts on their personal situation (Feenstra et al., 1998).
The difference of these two views can be seen as the difference between private and public adaptation. If adaptation is initiated by individuals, households or private companies the adaptation is private. If the adaptation is initiated by the government, irrelevant which level of government, it is public adaptation (MacCarthy and Intergovernmental Panel on Climate Change, 2001, The World Bank, 2009).

If climate change adaptation measures are not adequately designed and implemented to manage the climate change impacts, an adaptation deficit or adaptation gap is created (Figure 6). The deficit represents the additional effort needed to correct the lack of climate change adaptation. During the acceleration of climate change, this deficit has the potential to grow over time and thus the cost of adaptation will grow over time(The World Bank, 2009, Schipper et al., 2008).

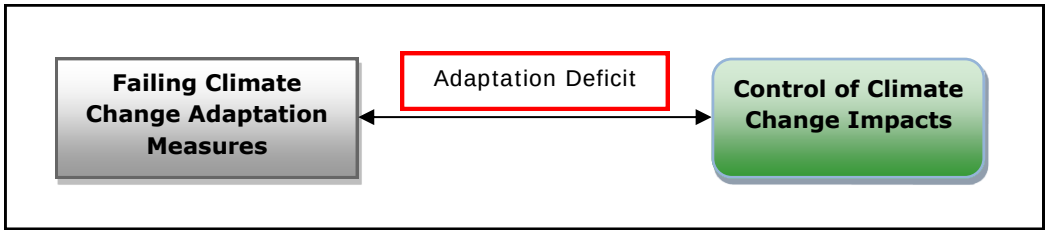

Figure 6. Schematic resemblance of adaptation deficiency

It is possible that a measure which was initially chosen to reduce vulnerability to climate change hazards, eventually turns out to increase vulnerability, this is called maladaptation (De Loë et al., 2001,

Schipper et al., 2008, The World Bank, 2009, Barnett and O'Neill, 2010). Most of these measures are designed for short-term benefits but have a negative impact in the long term. For example, the use of air-conditioning in response to health impacts of heat-waves. The benefits of this type of adaption are direct, unfortunately the higher energy demand for using the air-conditioning will eventually cause more CO2 to be released in the atmosphere increasing the warming effect on the earth, thus this is a maladaptation. Maladaptation can be defined in 5 types (Barnett and O'Neill, 2010):

1. Increasing emissions of greenhouse gases.(see example above)
2. Disproportionately burdening the most vulnerable.
   When the adaptation measure increases vulnerability for those who are most at risk (minority groups or low-income households, etc.)
   In a river valley, the richer area is in the hills while the poorer area is in the valley close to the river. When the flood risks increases the government wants to implement an adaptation measure to protect the population. They place a protection dam in the centre of the valley. This protect the rich areas from floods but increase flood risk in the lower value. The poor part is there disproportionately affected even though they are the most vulnerable.
3. High opportunity costs
   When the costs (economic, social and environmental) are higher than an alternative measure
4. Reduce incentive to adapt,
   When an adaptation actions is causing people to experience less incentives to adapt by, for example, penalising early actors.
   For example government often decide to financially support farmers that are struggling to survive period of drought through drought assistance programme. Without these programmes some companies that would have gone bankrupt without droughts, were now maintained due to this financial support. The best farmers which prepare properly for the do not use the support system. This is an example were farmers are supported not to adapt but depend on the finances given by the government.
5. Path dependency
   If a large adaptation measure requires, for instance, capital commitment than cannot be changed in the future. It reduces flexibility to react to unforeseen adverse effects

Therefore, during the adaptation selection procedure, possible negative effects should be seriously considered preventing maladaptation.

3.2. Adaptation measures

In the process of choosing adaptation measures, the most effective measure with the lowest risk is often preferred and the adaptation measures can be ordered in no-regret, low-regret, win-win, flexible / adaptive management and high-regret options. Each of these groups has pro's and con's which should be carefully considered (for examples see table 1).

No-regret options: Adaptation measures that already have a net socio-economic benefit independent without climate change. This form of adaptation is not affected by the uncertainties connected to future climate change. These measures deal with the current climate variability while also building up adaptive capacity for future climate change. Thus the measures are justified (cost-benefit) for present and future projected climate. The measures are mainly near-term and are likely to be implemented because they are at least cost-neutral.
Low-regret options: Adaptation measures with relatively low costs that may have relatively high benefits. These measures are aiming at a maximal return on investment even though the certainty of a correct future climate change projection is low.
Win-win options: These adaptation measures have also other benefits, this could be an adaptation and a mitigation effect or it could be for other reasons implemented but also function as an adaptation measure. No-regret and Low-regret measures can also be win-win if they also add to other outcomes.

Flexible / adaptive management options: Incremental adaptation measures instead of large plans that need to be implemented at once. This management form reduces the 'wrong-risk'. If certain measures turn out to be non-beneficial they can be altered due to the fact that they are part of a (large) group of smaller measures. The course of the whole adaptation management can even be altered when new knowledge, experience or technologies become available.
High-regret options: These options are considered the large-scale options. Examples are resettling parts of the population or building a large dam. Due to the uncertainty in climate change projections, these expansive and mainly irreversible options should be considered with care and awareness of the risks. Tough risky, it is possible that in certain cases this would be the best possible solution (UKCIP, 2011;The World Bank, 2009).

It is important to stress that the differentiation of what is no-regret, low-regret or high-regret is not constant and is variable over time and space. A certain measure may be high-regret in one part of the world, but low-regret in another. Also, in time a high-regret may become low-regret or vice versa (The World Bank, 2009).

Table 1 adaptation measure regret options (UKCIP en TWB)

Regret option	Explanation	examples
No-regret	options that will produce benefits with or without climate change.	Multi-cropping, Mixed farming and livestock systems, Conservation and sustainable use of natural resources (e.g. Land conservation)
Low-regret	Options that produce high amount of benefits with low risks	Meteorological / seasonal climate forecast, Extension services targeted to new crops / water saving technologies, Diversifying community sources of income
High-regret	Options that are mostly irreversible and by that will have high costs if the measure turns out to be unnecessary or not operative	Net water harvesting infrastructure, Resettlement of a community
Win-Win	*"When an option is enhancing adaptive capacity as well as contributing to other outcomes"*	Enhancing biodiversity, Reducing overall exposure to risk
Flexible management	*"Based on incremental adaptation in that way reducing risks associated with being wrong"*	Diversify business activity, Reduce pressure on areas and systems at risk, Long term flexible sustainability plan

3.3. Principles of adaptation

There are a few popular adaptation principles that form the basis for a variety of adaptation measures. *Diversification* is a principle used in almost every sector concerning climate change. One could think of diversification of income, diversification of cropping, etc. The strength of this principle is the spreading of risk. If one form of income fails, the other flow(s) of income remains to support the family or business. The same with crops, if due to climate change one species of crop fails, the other maintains and produces yield for the farmer to live on. Choosing the diversification with care can ensure an income. Diversification is an important adaptation measures because the future climate is uncertain and because with climate change often the climate becomes more variable. A more diverse system is often less vulnerable to high climate variability compared to a system with low diversity.
Reforestation in its simplest form is planting trees. The importance and diverse implementation possibilities of reforestation should not be underestimated. Forests provide food security and other livelihoods, trees provide shelter from storms as well as energy.
Management of land use, water, energy, forests, etc., will increase adaptive capacity. Knowing what is happening concerning these sectors and planning how the natural resources are used and the

expected climate change impacts within these sectors causes a country to be much more resilient. For example water management; by installing a water infrastructure transporting water from a water rich area to a water poor area. Land management to controlling were, for instance, trees must remain to protect agricultural land from storm, etc. Correct and effective management is of capital importance. *Education and awareness rising* is also important especially for improving adaptive capacity. Adaptation measures can be available but if the people are not aware of the dangers of climate change they will not change their lifestyle or accept implementation of adaptation measures. Also if professionals wish to support climate change adaptation are not educated and equipped, their efficiency will be low.

Financial aid is especially used by global or regional organisation and by developed countries to give incentives for climate change adaptation. Examples of financial aid are micro insurance, micro loans, etc. Limited financial resources make it difficult to implement such measures. Another important flow of financial aid is that of national government to local government. This flow needs to be secured to enable local governments to implement adaptation measures explicitly for their own region.

4. METHODS

The Congo River basin region is predominantly occupied by forest and agricultural land, the population and economy is heavily dependent upon these two sectors. The population has been, and still is, growing rapidly especially the urban centre. All these people need access to drinking water, energy and a safe living environment. Their city, village or land needs to be 'safe', the population must be protected against the effects of climate change on their environment. This report therefore focuses on four sectors: water, forestry, agriculture and energy. These sectors have been selected based on their size and their role in fulfilling basic needs for the people within this region. Also the present state of certain sectors such as water (for example drinkable water supply) is such that focus on how to cope with the coming climate changes is more than necessary.
Other sectors are not discussed within this report, not all existing sectors are important for this region, or the financial and political situation makes them less profitable to focus on for now. For instance, working with financial measures can only be done when monetary means are available, this is not always the case and therefore the focus is not on that sector. Institutional changes can be made but are of high complexity, not just practically but most definitely culturally. Institutions need to be up and running to be changed, to start new institutions the needed means must be available. There will be a short portion on institutions and management due to its importance, but they are integrated within the four chosen sectors.

The most effective climate change adaptation measures were searched review the existing literature. The measures were split in a group already used within the CRB, and measures applicable but not yet used within the CRB. Based on books and online available literature (both scientific and grey literature) the climate change measures were selected.
The measures selected are listed in the 'Climate Change Adaptation Table' (see appendix and also chapter 4). It includes the measures, a description, and a reason why it is applicable and, if available, a link to a practical example of the measure.

During the literature search we observed that little is known about this specific region concerning climate change and only a few publications were found which focus on the central African region. A big part of the information from within the region originates from the NAPA's and NC's found on the UNFCCC website, and publications from The World Bank and NGO's.

5. CENTRAL AFRICAN ADAPTATION OPTIONS

The analyses of future climate change showed that within Central Africa Climate Change will cause an increase in higher temperatures and more variable rainfall with more frequent extremes (Haensler et al., 2013). Adaption should focus mainly on extreme events such as heavy rainfall events and heat waves. The dry spells will be longer, the rainy season could become shorter but more intense. The changes, of which only the main line is described here, will impact the functioning of the region. The impact analyses shows that higher temperatures will have adverse effects on plant / crop growth, floods may increase due to the more intensive rainfall and river flows will become more variable. This chapter describes the possible adaptation measures to cope with the expected climate change impacts, for the sectors: Agriculture, Forestry, Water, Energy and Adaptive Capacity. These sector often interact with each other. For example water is used is used for agriculture and energy and deforestation affects the river systems. A complete overview of all the suggested adaptation options is given in the Adaptation Table (appendix 1).

5.1. Forestry

Within the CRB, there is still about 2 million km^2 of tropical and seasonal forest types. 30 million people of 150 ethnic backgrounds live in these forests. Though the forest contains about 4000 species of which 70% are endemic, about 60% of the forest is seen as industrially exploitable (CBFP, 2006). Climate change impacts can potentially increase the pressure on these systems. Climate change combined with bad forest management could have large impacts on the forest ecosystems and both the timber industry as well as the people depending on the forest for livelihoods. Changes in temperature and rainfall patterns may cause the evergreen forest to expand more to the north and south. Also the ecosystem carbon capture may increase, which in itself is a potentially positive effect of climate change (Ludwig et al., 2013).

Reforestation is a major part of both the climate change mitigation as well as the adaptation practises. Reforestation improves and diversifies sources of livelihoods, protects against soil erosion and soil / rock slides. It prevents loss of soil fertility. Trees can protect surrounding agricultural land from storms. Reforestation can balance the hydrology of catchments by improving infiltration of water and reducing loss of soil by erosion. Choosing to let reforestation be an obligatory part of the timber industry preserves natural woodlands and provides income and energy to those involved. During reforestation tree species could be used which are adapted to the expected future climate. This will make the forest more climate proof. By setting up a regional forest and agroforestry seed centre, the existing species and species that have their growth / yield optimum in the expected future climate (for each region) can be grown / collected and stored. In this way species can be chosen specifically for the local situation and can be provided for reforestation. If the seedlings (or seed beds) or partly grown trees are needed to be planted depends on the local situation. Seed banks have been set up in different African countries like South-Africa, Ethiopia, Niger, Kenya, etc. Seed banks can be national but also smaller community seed banks can significantly increasing adaptive capacity by reducing genetic erosion, conserve and enhance IN SITU diversity, maintenance of local genetic resources and seed security etc. Seed banks are not just for forestry, but also for agriculture, agroforestry, nature conservation, etc. (Worede, 2011, Albrecht and Monodi Oloo, 1993, Vercoe and Midgely, 1993) . The seed centre can hold an important task in the diversification of the forest. On could look at the diversification of tree species, as mentioned in precious paragraph, but also at de diversification by combining agriculture with forestry: agroforestry. For agriculture seed banks are important and will become more important in a changing climate as seed banks can facilitate in introducing new varieties.

Agroforestry is an old and proven method for diversification of income and spreading of risk to increase income and food security. By implementing for example the Modified Taungya System (MTS) both agricultural and forestry methods are used by the same farmer. The MTS stands for mixing trees and agricultural crops (see Figure 7). The first three years of using the MTS it is clearly an agroforestry system, as the trees grow and form a closed canopy, the farmer can focus on tending the trees to maturity after which it can be used for timber, energy, etc. The crops and tree cultivation are complementary, not competitive. There are varieties of complementary activities possible like small-scale trade, farming of poultry, bees or livestock keeping. To cope with climate change, the MTS provides food security, erosion control (the trees keep the soil together, less will be lost), soil fertility (trees have a fertilizing effect on their environment) and moisture balance as well as an addition source of fuel (wood), all of which are important in climate change adaption creating a buffer for the local environment when dealing with the changes. MTS has been successfully implemented in the Offinso forest district in Ghana, were it significantly improved the food production (Kalame et al., 2011).

Figure 7, example of MTS plantation in Ghana (www.fcghana.org)

Government officials also need to look at the present state of national forest management. To understand the state of the forest and the bottlenecks, a forest inventory can be done. Most of these inventories can be through remote sensing, using satellite images. But also on-ground monitoring of part of the forest can be an important part of it. A sustainable forest management plan connected to forest legislation can make a big difference, even more when management is based on a well-researched and continuously monitored forest inventory. Proper monitoring well ensures that climate change impacts are observed in time and that appropriate measures are taken in time.
Through forest management future energy supply, livelihoods and so on can be assured for due to the fact that the management has adapted to the changing climate. One cannot manage something of which the state and strengths and weaknesses are not known, on the other hand the magnitude of the forest can be a constraint in monitoring it. With this a balanced and well thought through plan should be designed how the inventory and monitoring of the forest can be done most efficiently keeping in account the capabilities present. There are already different monitoring systems in place however this systems could be improved also looking at possible climate change impacts(CBFP, 2006).

5.2. Agriculture

More than 80% of the rural communities depends on agricultural and forest activities contributing to large of the total economy of the region (Sonwa et al., 2012). Climate change is expected to put extra constraints on the agricultural sector. Increased interannual rainfall variability, greenhouse gas concentrations and more concentrated rainfall periods combined with longer dry spells will put dry land crops and rain fed agriculture under high pressure. The long dry spells initiate lack of water while during erratic rainfalls there may be floods that seriously damages any crop or pasture and thus weaken the economy (Ludwig et al., 2013). In this paragraph, suggestions are made that can assist in coping with these agricultural climate change impacts.

Diversification is a well-known and proven principle within climate change adaptation (see §2.2). Especially within the agricultural sector there are a lot of possibilities for this risk spreading practise. One could think of diversification in crops. Instead of cropping one species, a farmer could crop more species with different optimal climates. In this case the risk of crop failure is smaller due to the fact that if one crop fails, the other crops could yield well. This specific form of diversification is to deal with uncertain weather conditions: timing of the rains, temperatures, hours of sunshine / shade, etc. On the other hand it also limits the chance of overall maximum yields, as not all the crops will do equally well, they are picket out on the bases of yielding optimally in slightly different climatic circumstances. The exact crops chosen must be considered with care, taking in account present and expected future climate as well as the boundaries of optimal climatic conditions of the crops. Another form of diversification is diversification of income. Diversifying income by adopting an agro-sylvo-pastoral system, combining both livestock as well as crop cultivation could be effective in some regions. To ensure and income, even if crops fail, the farmer or family member could choose to participate in non-agricultural activities. It reassures a family of monetary income though it might also pressurise the family in time-management and task division (who will do the chores of the person who is now out working etc.).

In this region, the potential agricultural product is not reached on most of the field and farms. Improved land, nutrient, pest and weed management could dramatically increase agricultural production in the regions. When developing the agricultural sector it should include climate change adaptation, making the region “climate proof”. It is necessary to better integrate climate change adaptation into the different agricultural institutes and climate change adaptation needs to become part of the development (and development part of the adaptation).

Adaptation can also be implemented in small changes of current practices. A farmer can choose to crop a different variety, but remain farmer and operate as before. If the timing of the rainy season changes, the farmer could choose to change the timing of planting and harvesting. If crops do not reach normal yield, a farmer could choose to use extra fertilizer to strengthen the crop. To improve yield of pastures, the zero-grazing technique could be implemented. This means that the livestock will not graze in the pasture, but the grass is cut regularly and then fed to the animals. The yield of grass is higher, assuring food for the animals and so income for the farmers. However this technique requires more time investment. In respective of climate change agricultural production has to increase by improving management.

To be less dependent on rainwater, and to reduce the impact of shifting precipitation patters, farms can collect rainwater in the rainy season and use that in the times of drought. This is called rainwater harvesting. Also growing crops using irrigation techniques reduces the dependency on rainwater and thus reduces the risk of crop failure due to lack of rains.

The described techniques spread risks and can improve food and income security. It is possible that changing current practises is not sufficient. Adaptation measures on larger scales should than be considered. Changing the area under cultivation for example promoting clay soil farming. In clay soils water is kept longer by the soil structure and nutrients are more available. Building an irrigation infrastructure to transport water from water rich areas to water poor areas. Improved food stocking techniques helps in overcoming a time of shortage, these stocks should than be well managed and secured to prevent theft or loss of good food due to errors. A veterinary and phylosanitary services could be launched to provide farmers with helping hands in keeping livestock healthy and minimise loss of crops due to diseases. The services can also provide training to optimise for example livestock raising techniques.

The agricultural sector can be seen as flexible, there are many opportunities to adapt to the changing climate. As explained, not all of these measures need to be expensive or risky, but they do require careful research before implementing. Trying the cheapest option because it's the cheapest might eventually turn out to much more expansive due to losses and damages it could not prevent, which other more expensive options might have. Please take into account that situations differ per location, it is important to invest in research to determine the best options per local area. In the choice for adaptation options the free choice of farmers to or not to adapt should not be underestimated. Most farmers will not allow adaptation measures on their farm if there are not informed about climate change and the expected risks, and if they did not have the opportunity to be part of the process of selecting adaption measures. Including their knowledge of the local area and the farming practises can enrich the research for best adaptation measures significantly and increase the willingness of participation in the implementation of the measures.

5.3. Water

The Congo river has been known for being a stable, reliable source of surface water. Climate change will not stop the river from flowing, the opposite is more likely. The annual runoff of water could increase and therefore more water needs to be able to pass through the river system. The increase of both dry spells and erratic rainfall may cause the river to become more dynamic. More runoff will cause more soil degradation and will have adverse effects on the soil fertility and consequently on the food security. For human safety as well as the livestock branch of agriculture, providence of drinkable water must be assured. Today this is already troublesome in some areas due to rapid population growth, the effect of climate change such as longer dry spells will worsen the pressure even more. In the coming paragraphs the focus will be on water management, flood prevention, drought management and drinking water supply.

For the implementation of different adaptation measures and assures that the water sector can adapt to climate change there is a need for improved water management throughout the region. What the water sector needs most is solid management, this can be implemented in different forms. Local water boards with the responsibility to foresee, investigate and produce solutions for water related issues could be set in place. This water board could start out with collecting water data and creating awareness among the officials as well as the people what the present state of drinking water, surface water and groundwater is. Based on this information, a water source management plan could be written. It could therefore function as an implementing body for governmental legislation and planning as well as a communication vessel for the needs of the people concerning water towards water management and legislation. The actual tasks and framework of action can be locally determined based on the needs and possibilities in each country.

To prevent a shortage of water during times of drought a diverse group of soil water conservation techniques can be implemented. These techniques can include mulching, contour ridging, terracing, etc. (see Figure 8) In this way water is kept in the surface soil for a longer period of time and by that increase the Crop Water Productivity (CWP).Improving soil water holding capacity reduces the risks of dried out soils.

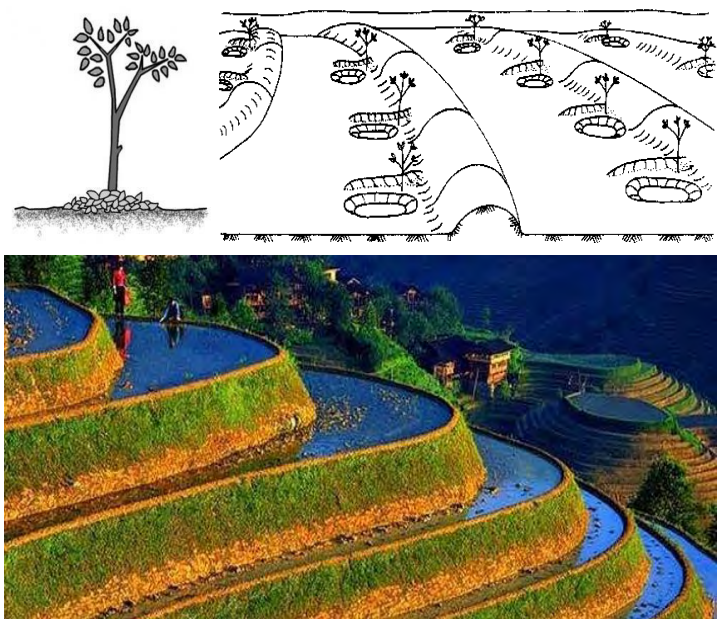

Figure 8, soil water conservation techniques. upper left is mulching (covering of area around plant), upper right is contour ridging and in the bottom is a picture of the terracing technique

Soil water conservation techniques might not be sufficient to overcome a longer period of drought. The reviving of rainwater harvesting (RWH), which is simple but effective, will cause annually enough water to be available (see figure 9). This technique is applicable in both small and large scale projects. Farmers could for example use this water for irrigating their crops especially fruits and vegetables.

Figure 9, small scale RWH in Ethiopia(www.waterworld.com)

During times of drought the supply of drinking water is even more pressurised than normally. Solutions to providing drinking water could be as simple as drilling more wells which can supply a community of clean drinking water taking into account possible lower water levels during the expected droughts. Storing water in times of abundance is easily applicable and can save the lives of many who are in need of drinking water in the times of drought. Storing of water can be organised per village, community or area and can thus be applied on different scales. A Public Water System (PWS) is an effective way of transporting drinkable water to the areas in need. A PWS is a large investment and often complex to manage, though many countries have partially implemented such a system. The key

for climate change adaptation is here that when designing the drinking water supply systems they are developed to function under a range of future climate. The systems need to be capable to supply enough water also during periods of droughts and should be not be destroyed or polluted during floods

During the shorter rainy season, the amount of rain falling per day is expected to be increased which increases flood risk. To make the rivers and dredges able to handle the larger amount water they can be dredged or widened, allowing more water to be able to pass through. River systems should be able to carry more water during peak flows and there will be longer periods with low flows. In critical areas, river stabilisation techniques can be applied such as river bank design, dykes, dams, spaces reserved for overflow, etc. with great focus on human safety as well as taken in account the dynamics of the river in future year.

The logistics behind water transport are very important, although even more important may be that the water that is transported is of sufficient quality, so it can be used for human consumption. To reduce back pollution of water, building water treatment plants will improve clean water availability. This will have a positive effect on health and productivity of the population.

5.4. Energy

The main sources of energy which will be affected by climate change in the COMIFAC countries are biomass and hydropower. Our analyses shows that climate change will not reduce the total hydro power potential but energy supply could become less reliable due to more variable river flows (Ludwig et al., 2013). Also total biomass production will not reduce due to climate change but a more variable climate will increase the pressure on forest ecosystems (Ludwig et al., 2013).
The continuing population growth and development in the region will increase the energy demands. When increasing the energy supply in the region it is important to take climate change into account. Hydropower is an attractive source of energy in the region and there is definitely potential in to hydropower in the region. It is however important to realise the water availability in the future will become less variable. As a result energy supply from hydropower could become less reliable. It is therefore needed to develop a more diverse energy supply system to also guarantee power supply during droughts.

Hydropower energy does not only have to come from systems. There also many local opportunities for small hydro stations. These stations can provide energy for a significant number of households and could reduce biomass and charcoal use. A micro hydro station can be developed near small towns to provide the town with energy. The local communities can manage their dam themselves, for which education and training is necessary. Other forms of renewable energy sources such as solar or wind energy should also be promoted and can be excellent options for local energy supply. Starting up pilot project for different kind of renewable energy sources can clarify which kind is most efficiently usable for which area without the risk of investing in big projects that are not tested beforehand.

In addition to renewable energy source also recycling of waste can be a source of energy. An example is the forming of ‘Briquettes’ (see Figure 10) out of waste products (www.gvepinternational.org). Briquettes are pieces of charred sawdust, agricultural residues or charcoal waste, the sawdust is waste and can be purchased for small prices or can simply be collected from forest cutting location. Forming ‘Briquettes’ can be done with limited investments and technology (though providing machinery does significantly increase production) and therefore creates employment and income for the people.

Figure 10, Small business selling 'Briquettes' (www.gvepinternational.org).

It is important that the damage done to the forest and ecosystem, but also to human health, through the use of wood as biomass energy should be reduced. Planning and implementing a wood-energy programme that includes legislation for forest management to minimise the cutting of natural forest, but could also provide safe wood stoves for those who use open fire or other forms of unsafe (self-made) equipment and education to use, or promotion of, other forms of energy.

To cope with the increasing energy demand of a growing population, energy saving education plans can be considered to teach the population to use energy as efficient as possible. Through the local schools, radio and television programmes, and other form of communication the information can be brought to the people. Locating small energy businesses for (such as Briquettes salesmen) and elaborate their function with an information facility function to provide education on safe and efficient energy use. It is important activate people to want to make a change for by personal motivation.

In terms of dam management there is an important link between the water and energy sector. For optimal energy production there is the aim to have as much water as possible in the reservoirs. However if reservoirs are completely full and there is a lot of rainfall upstream lots of water needs to be released from the dam which can cause large scale flooding downstream. For example the water released from the Lagdo reservoir in Cameroon, in September 2012 caused large scale flooding downstream in Nigeria. To reduce the risk of flooding reservoirs should not be at full capacity before the wet season. However, this could reduce energy supply if there is lower than expected rainfall during the wet season. These trade-offs between reducing flood risk and optimising energy production will become more problematic to manage in the future due to climate change which will cause more variable river flows. However there is a great need to improve dam management plan to adapt to climate change.

5.5. Improving Adaptive Capacity

When changes are happening it is the way and capability of dealing with it that will determine the vulnerability and consequences (see chapter 2). The adaptive capacity within the CRB is generally low. Even if the population is aware of the climate change issues and willing to act, there are many other barriers to adaptation. Next to the political unrest in the area, lack of monetary and material provision, management, education and governance will keep the adaptive capacity low. The climate is already changing, lacks in adaptation is impacting the region. A few examples of adaptation measures are given within this paragraph concerning education, early warnings systems, infrastructure, management and awareness rising that higher the overall adaptive capacity to climate change.

Early warning system

"It is much more effective to evacuate people before a flood than to rescue people during the flood… It is much more effective to support farmers to find alternative livelihood options than to provide food aid when the harvest has failed." (IFRC, 2008)

A warned farmer can decide to cultivate a different crop because he now knows that the season will not fit the needed environment of the crops he would otherwise cultivate. Communities can be assisted in evacuation after they have been warned that due to heavy rainfall further upstream the river nearby will flood soon. Lives can be saved, incomes secured if an early warning system is up and operational including effective communication and action.

Due to scientific developments humanity is now able to better predict the future weather, extreme events. Knowing what to expect gives the advantage of being able to prepare for what it is that is coming. An early warning system is not just about knowing what might happen, but just as much about how to communicate and effectively respond to the gained knowledge. An effective early warning system combines science with problem solving and communication, it requires a collaboration of different sectors, specialists and organisations.

Early warning systems come in different forms and shapes, focussing on different scales (local, national, regional, global). Many specific early warnings systems exist, for example: hurricane warnings, tsunami warnings, drought warnings, etc. What kind of system is needed depends on the area and the characteristics in which the early warning system has to function.

Within central Africa, agriculture is one of the main income generators, the population is depended upon it for food security, income and other livelihoods. The agricultural systems are dependent upon the seasonal weather conditions and therefore installing an early warning system for weather conditions focussing on the agricultural sector, a hydro-agro-meteorological warning system, will reduce risks of crop failure and all its consequences. How to communicate the information most effectively is very much dependent on what kinds of media are available. Television, radio, mobile phones, newspapers but also a warning system by sending out volunteers to warn people personally and offer possible solutions or help with evacuation, depending on the need (NAPA Rep. of Burundi, 2007, NAPA Rep. of Rwanda, 2006).

Early warning systems are not something new, establishing and maintaining such have been part of national and international goals for several years. In central Africa, this has also been endeavoured, though socio-economic crisis and other forms of political unrest have caused most of these initiatives to end or be strongly limited. Reviving and improving early warning systems should be high on the priority list to reduce vulnerability to future extreme events.

Education and awareness rising

Making the population aware of climate change and possible impacts and opportunities that it brings, is an one of the most important things to do. If one does not know what the impact of a certain event may cause, this person will never think of adapting or allow changes suggested by government or other institutions which influence his or her life to happen. People have through time shown themselves creative to deal with problems, to know what will happen to the climate and how that will impact each of his or her personal lives will give range to that creativity and could cause people to come up with personal adaptation options. Lack of education on possibilities or effects of certain choices will cause people to choose mainly for short term solutions or to choose for option that are maladaptation options or leave adaptation deficits to deal with will come back to them at another time.

Management and integration

For successful climate change adaptation in the Water, Energy and Forestry and agricultural sectors improved management at different scales is necessary. However these sectors should not be managed in isolation. Climate change and future development will increase the linkages between the different sectors. The demand for water, agriculture and energy resources will increase while at the same the pressure will increase due to climate change. Improper managed hydropower dams can cause large scale flooding. While excessive water use by the agricultural sector could reduce energy production. When developing a new large dam for hydropower production not only the energy sector should be involved other plans can damage drinking water facilities, ecosystems and livelihoods downstream. Within forest management a certain area of forest might be fenced to protect the ecosystem, but if that forest was the basic provider of livelihoods to a small village, the consequence might be devastating for the local people. It is of utmost important to make integrated project plans when designing and implementing climate change adaptation measures.

Land management and land use planning has not yet been discussed before although it is very important to adapt future land use to climate change. Also improving local, national and international infrastructure increases adaptive capacity by enabling transport of food, water and other resources. Also if evacuation is necessary, a good roads systems will make this possible and diminishes the needed amount of time which increases the human safety and reduces economic damages. Also erosion control will become more important because increased extreme event will result in higher erosion risks. These examples discussed above show the importance of including different sectors in climate change adaptation.

Often the measures concerning climate change adaptation and the measures concerning development are not co-ordinated while often they have very similar goals. Development plans and climate change adaptation plans are written in separation. Climate change adaptation should not be the responsibility of only the department of environment because climate change can affect the whole economy, agriculture, infrastructure, national safety, food and water security. Therefore climate change adaptation should be seen as an important part of the different ministries. Development is a strong adaptation measure if climate change adaptation has been taking in account. Developing non climate change proof projects could be lost investments. The integrated approach is strongly recommended.

5.6.Mainstreaming and Funding Climate Change Adaptation.

Most of the COMIFAC member countries still have incredible development challenges. The general income tends to be low and there are still high poverty rates. To feed the growing population significant increases in agricultural production are necessary. Also in terms of water management there are still lots of challenges but also opportunities. For example the further development of hydropower in the Congo basin could provide a basis for further economic growth. These immediate development needs are overall more important than climate change adaptation. However future development also creates opportunities for adaptation. To avoid wrong investment and to reduce future cost of adaptation, climate change issues should be integrated in future development plans. This is especially the case in the water, energy, agriculture and forestry sectors. Ideally climate change adaptation should be mainstreamed into sustainable development. However this is easier said than done. Even the most developed countries with large R&D budget still struggle with mainstreaming climate change adaptation. The complexity of the problem, the long term horizon and the uncertainties make climate change adaptation a difficult issue to integrate into on-going governmental decision making.

Given that the ideal situation would be that climate change adaptation needs to be mainstreamed into climate change adaptation would go against the idea to develop separate adaptation projects. However, we would like you to argue that this is not case. There is need to develop adaptation

projects to fulfil the most immediate adaptation needs and more importantly to learn how to integrated adaptation into sustainable development.

One on the most important next steps in the process would be to define adaptation projects which could be funded by the different donor programmes. The reports of this project provide a building block to define these projects. Given the limited capacity, knowledge and experience with climate change adaptation. An important aim of these projects should be building the capacity and know-how considering climate change in the region. This is probably as important as the immediate adaptation benefits of such projects.

6. CONCLUSION AND RECOMMENDATIONS

Within the region there is very limited documented knowledge and experience in relation to climate change adaptation. However there are many adaptation options which have been tested and described in other regions of the world which are useful for the COMIFAC countries. There is an urgent need to improve the knowledge base on climate change adaptation in the region. On-going activities should be better documented and there is need to develop experience, expertise and capacity in relation to climate change adaptation.

As a result of the lack of documented experience with adaptation in the region we can only give relatively general advice on the use of adaptation measures in the region. Most of the future climate change impacts will be felt through a more variable climate and adaption should thus focus on reducing the vulnerability to climate variability. . Adapting to *future* increased climate variability can be very well combined with improving management of the *current* climate variability. This can be done for example by spreading of risk through diversification and by improving the preparedness for extreme weather events, droughts and floods.

For the *Forestry* sector the most important adaptation measures should focus on the prevention of forest degradation. This means reforestation of areas where forest has disappeared due to either natural causes or human activities. Also increased introduction of agroforestry should be promoted to reduce erosion.

For the *Water* sector adaptation should focus on reducing flood vulnerability through development of flood prediction system, avoiding development in flood prone areas and building flood preventing infrastructure (dykes and levees) were needed. In addition it is important to adapt dam management policies. As river flow regimes will become more variable and extreme, on average less water should be stored in dams to prevent dam failure and avoid emergency releases which can cause floods downstream.

Adaption in the *Agricultural* sector should focus reducing vulnerability to higher future temperatures and increased climate variability. New varieties should be developed and/or introduced which are adapted to higher temperatures. Also pest and disease control will become more important in a warmer climate. To adapt to future climate variability programmes should be started to improve the management of the current climate variability. This can be done through *e.g.* diversification of farming systems and improved soil water and nutrient management.

For the *Energy* sector it is important to adapt to the lower reliability of future hydropower production. To do this there is a need for diversification in the energy sector. In addition to large hydropower plants more local energy production systems are needed. For example by using biofuels, solar energy and micro-hydropower plants.

Future climate change will affect water, energy and food security and many adaption options focusing on improving these resources securities. Already without climate change many of the COMIFAC

countries have problems with water, energy and/or food security. It is important that measures and policies which are developed to improve these securities take into account climate variability and change.

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APPENDICES

Appendix 1 Adaptation measures table inside region

Adaptation table		Existing adaptation measures, previously published
Legend:		
Adaptation measure		Title / name of proposed measure
sector:		
	A	*Agriculture*
	F	*Forestry*
	W	*Water*
	E	*Energy*
	M	*Management*
Description		What is the proposed measure practically about
Rationale		Why is this measure effective. In what for circumstances can this measure be used
Reference		Sources

Nr.	Adaptation Measure	Sector	Description	Rationale	Examples (UNFCCC and others)	Reference
1	**Agriculture**					
1.1	*Crop (species) selection*	*A*	*Cultivate crops more suited to the new climatic circumstances. For instance slower or quicker maturing varieties to cope with changes in rainy seasons. Drought or heat resistant crops.*	*Crops that are used up until now could possible no longer grow or deliver enough yield due to the new climatic circumstances. Changing to crops that are delivering satisfactory yield in the new situation is therefore reducing risk to crop failure and thus increases food security.*		*NAPA Burundi, NAPA Rwanda, Schulte-uebbing 2011, Feenstra et al., 1998*
1.2	*Introduction of species varieties*	*A*	*Diversify cropping by cultivating several crop species, all with a small difference in optimal climatic conditions.*	*Diversification of crops is a spreading of the risks concerning climate change damage.*		*NAPA Rwanda, Lipper et al., 2010*
1.3	*Crop timing*	*A*	*Switch seasons of cropping, alter times of sowing . Modify early and late planting dates.*	*adapt timing of cultivating to the altered climatic conditions so that the probability of a successful harvest in higher*	*Mixed cropping in Burkina Faso*	*Schulte-uebbing 2011, Feenstra et al., 1998*
1.4	*Change the area under cultivation*	*A / F*	*Move the area under cultivation to an area in which the future climate will be suitable*	*In this case loses of crops due to climate change can be avoided by cropping in an area that will be / remains suitable for that crop species*		*Schulte-uebbing 2011, Bwalya& Friedrich 2002*
1.5	*Expand area under cultivation*	*A / F*	*Expand are under cultivation to also cultivate crops that previously could not be cultivated*	*Changed climatic circumstances allow other crop species to be cultivated next to what is currently done. This diversifies crop species and thus spreads risk, gives a higher yield and thus a higher income*		*Schulte-uebbing 2011*
1.6	*Maximize agricultural activity on clay soils*	*A / W*	*Clay soils have a high water-holding capacity which can be taken advantage off during droughts and longer periods of dry spell*	*If the soils have a higher water-holding capacity, the efficiency of water use is higher, less water is lost due to evaporation or leaching and the crops can endure longer periods of dry spells than those cultivated on other soil material*		*Schulte-uebbing 2011, Dinar et al., 2008*
1.7	*Promote stocking techniques for agricultural products after harvesting*	*A*	*Store foods safely, protected from rot and pests, for times of need*	*If storage techniques that can prevent pests and / or rotting of foods, these foods can be stored successfully for a longer period of time providing food in case of lack.*	*Food storage in Egypt*	*NAPA Rwanda*
1.8	*Increased (N) fertilization*	*A*	*increase amount of fertilizer used, reuse of manure or inorganic fertilizer, or increase other methods of fertilization*	*increases fertilization enhances crop yields, the crops are less impacted by climate change than non fertilized crops for they have become stronger due to provided nutrition.*	*Nine-Maize Hole Planting in Kenya*	*Schulte-uebbing 2011, Lipper et al., 2010*

Nr.	Adaptation Measure	Sector	Description	Rationale	Examples (UNFCCC and others)	Reference
2	**Livestock**					
2.1	promote zero-grazing breeding	A	Grassland management: instead of letting the animals graze, the grass is cut and then fed to the animals. This technique improves the grass utilization	More security of fed animals during droughts, increased productivity and resilience.	Goat breeding in Moroto and Nakapiripirit, Uganda	NAPA Burundi, Morrison 2003, Lipper et al., 2010
2.3	Promote agro-sylvo-pastoral systems	A/ F	Income diversification by promoting agro-sylvo-pastoral system: combining pastoralism and agriculture on household level, adapted to the new climatic conditions	Diversification of income sources, spreading the risks. For a pastoralist to also cultivate crops, and vice versa, highers the probability of food security and income during extreme weather events and change in climate		NAPA Rwanda, Lipper et al., 2010
2.4	Promote veterinary and phytosanitary services	A	"improving livestock health through the provision of veterinary services and treatment of animals for diseases". This also counts for stronger crops due to phytosanitary services	"By increasing the health of the animals the milk production increases. The efficiency improvement results in increased production and income but with a smaller more efficient herd causing a smaller impact on the resource base". For crops that withstand or survive pests, phytosanitary services should be put in place	Improving milk production in Cajamarca, Peru (Spanish website)	NAPA Rwanda, Lipper et al., 2010
2.5	Improving livestock raising techniques	A	Improve used and introduce new raising techniques for livestock increasing health, and thus survival rate, of the animals and increases the income of the farmer	teaching and promoting new techniques for growing food for the animals, zero-grazing techniques, building / maintaining shelter for the animals, water supply, etc. to improve health of the animals which improves lifetime of the animals and income for the farmer. Healthy animals can withstand climate changes better than less healthy animals	Goat breeding in Moroto and Nakapiripirit, Uganda	Schulte-uebbing 2011
3	**Agroforestry**					
3.1	Modified Taungya System (MTS)	F / A	MTS is an agroforestry system involving inter-planting trees (with edible fruits) with agricultural crops. Providing food security, reduces erosion and provides additional source of fuel wood / timber / fertilizer / etc.	"Mixing trees and shrubs with food crops provides an opportunity for farmers to improve their food security". Diversifying income spreads the risks. Trees improve soil fertility and soil moisture through increasing soil organic matter	The modified taungya system in Ghana's transitional zone	Schulte-uebbing 2011 --> Kalame et al., 2011, Roberts 2009, Lipper et al., 2010
3.2	Keeping trees as wind / protection breaks	F / A	planting and growing trees on strategic place to protect the crops from damages	"diminishes the effects of extreme weather event such as heavy rains, droughts and wind storms. Besides protecting crops, the trees also function as natural fertilizer for the crops through increasing soil organic mater and they have an erosion controlling effect		Schulte-uebbing 2011, Lipper et al., 2010

Nr.	Adaptation Measure	Sector	Description	Rationale	Examples (UNFCCC and others)	Reference
4	**Forestry**					
4.1	*Reforest stripped mountainous massifs*	*F*	*Reforestation to reduce erosion, protection against drought and aridity, provide natural fertilization of the soil and provides food / timber*	*Besides the mitigation effect of reforestation, the technique also provides adaptation by providing more stability for food and income*		*NAPA Burundi*
4.2	*Seek local and exotic forest species resistant to dryness and to diseases*	*F*	*Adapting to the expected climatic conditions by choosing species that are well adjusted to such condition, those already locally present as well as 'new' exotic species to introduce.*	*Species that are cultivated up until now could possible no longer grow or produce enough yield due to the new climatic circumstances. Changing to tree species that are delivering satisfactory yield in the new situation is therefore reducing risk of losses for this sector*	*Domesticating wild fruit trees in Botswana*	*NAPA Burundi, Roberts 2009*
4.3	*Rehabilitate existing forest resources*	*F*	*seed or cuttings of existing natural trees and shrubs that have been lost due to deforestation or other factors, to rehabilitate natural resources for food and other livelihoods*	*To rehabilitate natural recourses is to provide the communities with variety of food sources. Variety in Nutrition will keep the population healthy and stronger to deal with climate change. Rehabilitate the natural resources strengthen the ecosystem (biodiversity), allowing it to be stronger in coping with climate change*	*Moringa trees in Senegal*	*NAPA Burundi*
4.4	*Restoration of existing woodlots*	*F / E*	*"replant the areas of destroyed woodlots"*	*Reforestation for timber production and wood energy, keeping the communities and companies to look for wood in different places. By that preserving natural woodlots, and providing income and energy for the community*		*NAPA Burundi*
4.5	*Forestation of catchments*	*F / W*	*"Forestation of catchments to contribute to eco-climate system restoration"*	*Afforest the catchment prevents erosion and loss of fertility and balances evaporation of water. It also lifts up the adaptive capacity to erratic rains, and other extreme weather events.*		*NAPA Burundi*
5	**Drinking Water**					
5.1	*Development of public water system (PWS)*	*W*	*building a drinking water system to villages and communities (pipelines, taps, etc.), supplying safe drinking water*	*If a drinking water infrastructure is developed, safe drinking water can transported from water sources to areas with few to no water sources during draughts.*		*NAPA CAR, Soa Tomé e Principe*
5.2	*Drilling drinking water wells*	*W*	*providing more available drinking water by drilling more drinking water wells*	*Times of drought, longer dry spells, etc. can be bridge by providing more available drinking water to the communities.*		*NAPA Congo rep*
5.3	*Development of water storage*	*W*	*storing water from different kinds of sources to supply water, also preventing flooding by erratic rains*	*Storing water in basins or catchments (rain-water, ground-water, etc.) will ensure water supply during times of drought and can prevent damage during erratic rain*	*Shallow water basins in Turkana, Kenya*	*Schulte-uebbing 2011, NAPA Congo rep*

Nr.	Adaptation Measure	Sector	Description	Rationale	Examples (UNFCCC and others)	Reference
6	**Agricultural Water**					
6.1	Promotion of non rain-fed agriculture	A	Not depend only on the rainy seasons, other techniques such as irrigation techniques, rainwater harvesting, etc., can be promoted for cropping success	The timing and character of the rainy season(s) are likely to change. To be less depended on that rainy season, non rain-fed agriculture will help build food and income security		NAPA Rwanda, CAB international 2009
6.2	Expand area under irrigation	A	reduce area of rain-fed agriculture to non rain-fed by using irrigation methods . Irrigation water can bet taken from e.g. nearby rivers, rainwater harvesting or drop irrigation	providing sufficient water to the crops can boost yields by preventing water stress due climate change		Schulte-uebbing 2011
6.3	Reviving rain water harvesting	A / W	collecting and storing rain water to satisfy irrigation and animal husbandry in times of drought	"It reduces vulnerability to drought, the pressure on water points meant for drinking water and conflicts of drinking water utilization"	Water harvesting structures in northern Kenya	Schulte-uebbing 2011, Partow 2011, NAPA Rwanda, NAPA Burundi
6.4	Build irrigation infrastructure	A / W	"sharing irrigation water over agro ecologically and hydrologically diverse areas"	Investing in an irrigation infrastructure allows dry areas to be provided with water, causing farmers to be assured of water and by increasing adaptive capacity in the form of food security. Also conflicts for water can be reduces by transporting water from location with abundance to location with (possible) lack		Schulte-uebbing 2011, Rosegrant et al., 2010

Nr.	Adaptation Measure	Sector	Description	Rationale	Examples (UNFCCC and others)	Reference
7	**Surface water**					
7.1	Soil water conservation techniques	W	Mulching, contour ridging, terracing	these techniques increase crop water productivity (CWP) by using techniques such as mulching, contour ridging and terracing. Building of efficiency lessens risks		Schulte-uebbing 2011
7.2	Prevention and treatment of polluted water	W	endeavour to practically minimize water pollution and install water treatment plants to treat water and reuse	keeping clean and polluted water strictly apart, treat polluted water and reuse. Providing a more stabilized water production		NAPA Burundi
7.3	stabilisation of river dynamics of river courses	W	protecting the rivers surrounding landscape, communities and infrastructure by stabilization and correcting parts of the river that propose risk / danger. Including maintenance, building ridges i.e.	erratic rains can cause more water to flow through the rivers close to communities, infrastructure or protected landscapes. By maintaining, and correcting weak parts of the rivers, flooding will be prevented		NAPA Burundi
7.4	Widening and dredging of rivers	W	Apply basic river mechanics to allow higher flow of water through the rivers	allowing more water to run through the rivers will prevent or delay flooding		NC Congo
8	**Energy**					
8.1	Promotion of new and renewable energies	E	Implement other forms of energy sources such as bio-energy (biomass, biofuel (Bagasse or others)), Solar and Wind energy, Hydro-energy, etc.	Usage of other forms of energy, replacing wood energy and by that reducing deforestation, also produces more energy security, forms of income, etc.	GVEP International	NAPA Burundi, NAPA Sao Tomé e Principe, website GVEP
8.2	Promotion of hydropower (micro) stations	W / E	enlarging the electricity supply by building more hydropower stations. Small hydropower stations to promote living conditions of the rural population	The Congo River is a stable river, this can be used as energy source on different scales. Smaller hydropower stations can supply for a village or area. "without electricity, possibilities of production and improvement of the well-being of the population are inaccessible"		NAPA Burundi, NAPA Sao Tomé e Principe
8.3	development and construction of dams / dykes	W / E	Coastline / river basin protection from sea-level-rise by building dams / dykes	protecting communities, infrastructure, etc. from flooding by building dykes and dams. Possible to link with promotion of hydropower stations		NAPA Burundi, NC Gabon
8.4	Promotion of charring wood waste from logging companies (Briquettes)	F / E	To make briquettes from sawdust or other usable waste	replacing wood en charcoal energy reduces deforestation and pollution. Creating Briquettes out of waste is a sustainable energy source and can be made at low costs (depending on scale)		NAPA CAR, website GVEP

Nr.	Adaptation Measure	Sector	Description	Rationale	Examples (UNFCCC and others)	Reference
9	**Land Management**					
9.1	Make formerly swampy areas suitable for off-season maize cultivation	A / F	Due to longer dry spell, certain swampy areas can be used for cultivation	taking advantage of the changes is to use the now drier areas for cultivation of crops like Maize		Schulte-uebbing 2011
9.2	Erosion control	A / W	planting zone with trees and / or shrubs and replanting areas of destroyed woodlots. This will cause the soil to be less vulnerable to soil erosion due to, for example, erratic rainfall or floods. Trees and shrubs of choice are those adapted to new climatic circumstances	Plant cover prevents erosion by absorbing the kinetic energy of raindrops, it slows down the runoff and it keeps the soil surface porous.	Ngare or Mhindu ridging in Mozambique and Zimbabwe	NAPA Burundi, NAPA Congo rep, NAPA Rwanda
9.3	Construction of contour lines to control erosion	F / W / A	preventing erosion and deforestation by planting and cultivating in contour lines.	Implementing contour lines fixes the unstable grounds and slopes. Also plowing in contour lines on fields, perpendicular to the gentle slopes (works for gentle slopes only) prevents erosion by holding water containing solids		NAPA Burundi, Roose 1996
9.4	Improve (inter)national and local infrastructure	A / F / E	Increasing access to the market and other services by restoring or building roads, railways, etc.	improved infrastructure causes farmers to be able to sell off surplus after harvest. Food, wood and other basic needs can be transported further away and faster than previously. Increases adaptive capacity. People will be able to reach hospitals and other services quicker than previously		NAPA Congo rep, Feenstra et al 1998, NC Congo, Foster &Briceño-Garmendia 2010
10	**Agricultural Management**					
10.1	Promotion of non-agricultural activities	A	Set up and implement a plan to help people identify and / or develop other competences usable in non-agricultural jobs to generate income from other sectors than agriculture	diversification of income highers adaptive capacity, if the crops yield is not sufficient, the second income can still provide for basic needs		NAPA Rwanda

Nr.	Adaptation Measure	Sector	Description	Rationale	Examples (UNFCCC and others)	Reference
11	**Water Management**					
11.1	Installation of a technical body to coordinate the water sector	M W	creating a water board to take responsibility of the surface water and safety aspects of climate change adaptation and development. Goals are to provide clean drinking water to all inhabitants and to endeavour to create or maintain safety from flooding's i.e. Create an international collaboration for clean and safe Congo River Basin	installing bodies to manage and control priority measures will speed up the process of realisation. Good management practises should be taken in serious account. Including river mechanics and implementation of water management planning. See also adaptation points 7.3 and 7.4	Rand Water board South Africa	NAPA Burundi, Ashton 2002
11.2	Installation of national water data bank	M W	keeping water data organised to create awareness of the need of water in which areas. The possible uses of the water (drinking, irrigation).	water data bank could be established and maintained by the water board to create a scientific basis and awareness on what to be done and implementing water management	Regional water data bank project Middle East	NAPA Burundi
11.3	Develop and implement source protection plans for watersheds	W	develop and implement management plans containing basic zoning principles, demarcated protection zones, adequate natural buffering strips, land delineation, controlling land development and clarify land tenure and jurisdictional mandates. Create a broad level vision and strategy on regional watershed development	Poor land use practices is a threat to drinking water sources. By developing and implementing a proper land and water management plan (by for instance the water board), sprawl of the urban area and thus the slowly advancing beyond limits can be significantly reduces. This will safeguard public health and strengthen water sector investments		Partow 2011
12	**Forest Management**				-	
12.1	Make a forest inventory	M F	document the present situation of the forests	To know what has happened in the light of deforestation and biodiversity, and to apply adaptation measures, the present situation of the forests need to be know and clearly documented		NAPA Burundi
12.2	Work out / further develop sustainable forest management plans	M F	create, or further develop, forest management. Controlled / contracted allocation of forest management if needed due to the size of the forests. Management including, monitoring status of the forests, safeguard forest protection and afforestation areas, certification and verification forest concessions and Non-Timber Forest Products, promoting agroforestry, manage slash and burn agriculture, use of wood waste, energy efficiency, etc.	A sound forest management guarantees future energy supply, while simultaneously maintaining the natural resources base and stopping overharvesting of wood		NAPA Burundi, NAPA Congo rep, de Wasseige et al., 2010
12.3	Enhance the forest and agro-forest seed centre	M A / F	Organisation to keep germplasm collection, genetic resources, collaborate with other seeds centres around the world, support research activities such as silviculture, genetic variation, breeding systems, climatic analysis, etc.	A seed centre assists in preparing and go through climate changes by providing seedlings that are adapted to new climate, without losing the original genetic variation of the area through a genetic/seed database. It can provide seed security for local communities and create a healthy genetic variation which is also important for the crops and trees to be resistant against diseases.	Flood management in the Xai-Xai District, Mozambique	NAPA Burundi, Vercoe&Midgley 1993, Worede, 2011

Nr.	Adaptation Measure	Sector	Description	Rationale	Examples (UNFCCC and others)	Reference
13	**Energy management**				-	
13.1	*Set up a national wood-energy programme*	*M F / E*	*creating a programme that educates and enables different and more efficient uses of wood-energy. Safe wood energy use for household, etc.*	*Educate and promote (make available) for example safe stoves, more efficient and safe than open fire.*	*Practical Action East Africa's programme*	*NAPA Burundi*
13.2	*Develop energy-saving programme*	*M E*	*promote energy efficiency in government, businesses, households, etc. Set goals for certain time frame*	*less use of energy for the same activities causes less energy to be spilled, higher sustainability, higher adaptive capacity*		*NAPA Burundi*
13.3	*Design and implement renewable energy pilot projects for conventional water utilities and community based water-supply systems*	*M W / E*	*"carry out a technical assessment to identify appropriate renewable energy technologies for operating conventional water treatment plants, based on the technical evaluation, implement the simplest and most appropriate renewable energy solutions selected"*	*"This measure will lower the financial burden of fuel oil costs for water treatment plants". Renewable energy will lower the pollution, higher adaptive capacity due to independence of non renewable energy sources*		*Partow 2011*
14	**Education**					
14.1	*Training in basic techniques and water management*	*M W*	*Education of water management techniques on different scales.*	*equipping officials and experts to practically run and implement a sustainable and climate change proof water management*		*NAPA Burundi*
14.2	*Training and sensitization of the population on the economic use of water and energy*	*W / E*	*Set up and implement and education plan for the population to educate in energy and water efficiency*	*Increase efficiency of the populations water and energy use increases adaptive capacity due to the fact that less water / energy is needed for the same activities. In case less is available due to climatic factors, this will not have the same effect on population as previously*		*NAPA Rwanda*
14.3	*Promoting awareness of bushfire risk*	*F*	*Radio and TV broadcasts on the adverse effects of climate change and the effect of bushfire and deforestation now and in the near future*	*Informing people, and by that raising the awareness of risks of bushfires, will cause people to be more aware of their actions and the consequences of such. This decreases the number of bushfires and other forms of deforestation*		*Schulte-uebbing 2011, NAPA Burundi*
15	**Early warning management**					
15.1	*Setting up hydro-agro-meteorological early warning system*	*A / F / W/ E*	*"Installation or rehabilitation of hydrological and meteorological station to master hydro meteorological information and early warning systems for control of climate change hazards" Including a communication protocol to communicated findings to those in need of it*	*Predictions enable, for instance, farmers to take specific adaptation measures against the adverse effect of climate change. This reduces the 'surprise' factor when it comes to climate change impacts and enables the people to prepare for what is coming. This measure enlarges the adaptive capacity greatly if the findings can also be effectively communicated*	*Point-to-point radio in Isiolo, Kenya*	*NAPA Rwanda, NAPA Burundi*

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Contact:
Climate Service Center
Fischertwiete 1
20095 Hamburg
Germany

Phone +49(0)40-226 338-424
Fax +49(0)40-226 338-163

www.climate-service-center.de

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